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OVERVIEW OF MILLIMETRE WAVE BAND TO BE USED IN 5G

ADUSUMALLI MALLIKHARJUNA RAO, SK. SADDAM HUSSAIN & KOUSHIK BARMAN

Department of Electronics and Communications, Lovely Professional University, Punjab, India

ABSTRACT

5G is the most promising standard for next generation mobile cellular networks. It will definitely provide great speeds between 10Gbps to 100Gbps with enough capacity to accommodate huge mobile traffic. But the thing that separated 5G from 4G is the latency; the latency provided by 4G is between 40ms to 60ms, whereas in 5G it will provide ultra-latency between 1ms to 10ms. The standards for 5G will be set till 2020 and it will be applicable by 2022/23. In this paper we have discussed about 5G and its evolution, about millimetre wave communication, its characteristics, challenges and application areas.

KEYWORDS: Millimetre Wave, Channel Measurement, Blockage Sensitivity

INTRODUCTION

Mobile networking is a wireless technology than can provide voice and/or data networking, through a radio transmission. Mobile phone is one of the most famous applications of mobile networking. In past circuit switching was used to transmit voice over a network, then we moved on to use both circuit-switching and packet-switching for voice and data, now presently we are using packet switching only, this is how spectrum has expanded from 1G to 4G [1]. Today and in upcoming future wireless networks need to be improved for meeting the demand for increased data rate, improved capacity, reduced latency and good quality of service. We are in the 4th generation of wireless communication, so now research is going on for developing new standards for the next generation beyond 4G i.e. 5G. With increasing demands of subscribers definitely 4G will be replaced by 5G with the help of some advanced technologies like massive MIMO, device-to-device communication, millimetre wave communication, Beam division multiple access in massive MIMO etc. The technologies used in 4G like High-Speed Packet Access (HSPA) and Long Term Evolution (LTE) will be used as a part of future advancement. For this advancement we may use different methods, It may happen that we may use different spectrum access technique, increased frequency range, deploying large number of antennas etc. [20]

This whole thing started in 1970s, till now the mobile wireless communication has come a long way from analog communication to today's modern digital mobile communication providing the subscribers with improved data rate of megabits per second over wide area and few hundreds of megabits per second in a local area. We are going on well toward next stepping stone in future i.e. 5G.It is predicted that 5G will be in operation by 2020, hence immense research in going on in this field. The world is imagining a future where there is no restriction to the access and sharing of information from anywhere by anyone.

WHAT IS 5G AND WHY DO WE NEED IT?

5G is the name given to the next generation of wireless connectivity. It will provide great speeds and a good capacity. We are in the 4G now, having speeds of up to 150Mbps in areas of double LTE connections, 300Mbps for

LTE-A connections and Pocket-lint (the largest independent gadget news and reviews site in the UK) has predicted that the speeds will improve up to 1Gbps in 4G. This speed is more than enough, then why on earth we need something more, why we need 5G? It is sure that 5G will provide unbelievable speeds between 10Gbps and 100Gbps. But latency is the thing that is very important, in 4G it is between 40ms and 60ms. This is a very low latency but not able to provide real-time applications like in a multiplayer game we want our server to respond very quickly when a button is pressed. When it comes to 5G, they have promised a ultra-low latency between 1ms to 10ms. Then in future we can actually watch a cricket or football or any conference actually live without any delay. 5G is a technology that will appear to be invisible; it will be just there like electricity. Management of the available bandwidth is very important for improving the capacity, one idea is that as not all devices need the same bandwidth, we may provide bandwidth according to the needs and hence improve the capacity.

Some of the key technologies to be used in 5G are massive MIMO, device-to-device communication, millimetre wave communication and some multiple access techniques like beam division multiple access (BDMA). Everything around us will be connected to network, the sensors network, the ad-hoc networks, our accounts, laptops, pc etc. Analysis tells that by the year 2020, every person in UK will have 27 internet connected devices and 50 billion connected devices worldwide. This is definitely going to happen in future and it is given the name internet of things and beyond this it is internet of everything [20]. The devices connected may be mobile phones, tablets, watches, smart cloths etc. some may require significant amount of data to be transferred back and forth, the others may just need small packets of data, hence depending on these bandwidth can be allotted for the improvement of overall capacity of the system.

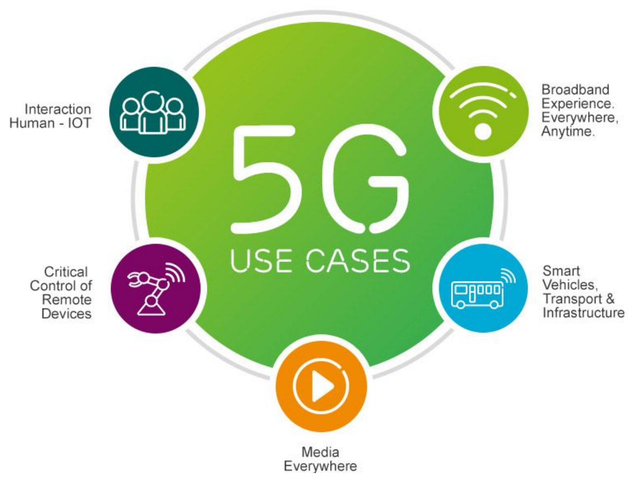

Figure 1: Things That Will Happen in Future [20]

EVOLUTION OF 5G

First Generation (1G)-1981: The 1G was based on analog communication. They had poor traffic density i.e. only one call per channel, poor voice quality and they were insecure without any encryption.

Second Generation (2G)-1991: The 2G was based on digital communication with different standards. Among these standards the most famous were GSM (Global System for Mobile), CDMAOne (Code Division Multiple Access One), IS-136, and PDC (Pacific Digital Cellular). GSM was the most famous of all; it's being used even now. GSM used a frequency band between 900MHz and 1800 MHz, they developed a technology called SIM for authenticate a subscriber for identification and billing purposes, and for encryption of data. Second to Third Generation Bridge (2.5G)-2000: In 2.5G the data was added along with voice. In between 2G and 3G a famous service called GPRS (general Packet Radio Service) was introduced, which provided services like send and receive e-mail and picture messages. They provide operation speeds up to 115kbps, which was increased up to 384Kbps by using EDGE (Enhanced Data rates for Global Evolution).

Third Generation (3G)-2003: 3G used a higher frequency bands and CDMA for data transmission with speeds up to 2Mbps and supported multimedia services like MMS. The famous standard in 3G was WCDMA (Wideband Code Division Multiple Access) which achieved speeds between 384Kbps and 2048Kbps. They continued using SIM authentication for billing systems and for encryption of data.

Fourth Generation (4G)-2007: 4G can provide speeds up to 150Mbps in areas of double LTE connections, 300Mbps for LTE-A connections and Pocket-lint (the largest independent gadget news and reviews site in the UK) has predicted that the speeds will improve up to 1Gbps in 4G., ad hoc networking model is used as a base as there is no need for a fixed infrastructure. The famous standards used are LTE-A (Long Term Evolution- Advance) by 3GPP and Wimax by IEEE. They provide latency between 40ms and 60ms.

Table 1: Difference Between 1G, 2G, 3G, 4G, 5G [23]

Technologies / Features	1G	2G/2.5G	3G	4G	5G
Evolution	1970	1980	1990	2000	2010
Deployment	1984	1999	2002	2010	2015
Data Rate	2 kbps	14.4-64 kbps	2 Mbps	200 Mbps to 1 Gbps for Low Mobility	10 Gbps to 100 Gbps
Famous Standards	AMPS	2G: GSM,CDMA 2.5G: GPRS, EDGE, 1xRTT	WCDMA, CDMA-2000	LTA, WiMAX	Not yet defined
Technology Behind	Analog Cellular Technology	Digital Cellular Technology	Broad Bandwidth CDMA, IP Technology	Undefined IP and Seamless Combination of Broadband. LAN/WAN/PAN/WLAN	Undefined IP and Seamless Combination of Broadband. LAN/WAN/PAN/WLAN
Service	Voice	2G: Digital Voice, SMS 2.5G: Voice+Data	Integrated High Quality Audio, Video and Data	Dynamic Information Access, Wearable Devices	Dynamic Information Access, Wearable Devices With AI Capabilities
Multiplexing	FDMA	TDMA,CDMA	CDMA	CDMA	CDMA
Type of Switching	Circuit	2G: Circuit 2.5G: Circuit and packet	Packet	Packet	Packet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal and Vertical	Horizontal and Vertical
Core Network	PSTN	PSTN	Packet network	Internet	Internet

5G ARCHITECTURE

In general a research have shown that a mobile subscriber stays inside for approximately 80 percentage of time and outside for approximately 20 percentage of time. From this scenario for a subscriber inside will receive a call when signal penetration through the walls, then that signal will undergo many losses and henceefficiency will be less, bit rate will be low and low energy efficiency. This is happening because there is only one base station at the middle of the cell site that handles all these. When it comes to 5G architecture it has different models for outside and inside. By doing so some of the penetration losses can be reduced. This will be implemented using massive MIMO technology by deploying hundreds of antennas. Normally in MIMO system we utilized two or four antennas, by using massive MIMO we are increasing number of transmitter and receiver antennas approximately between ten to hundred, by doing so we are increasing the capacity gain [1].

In massive MIMO network two things are setup for establishing a reliable network. First, a base station will be installed in a cell site with multiple antennas on it or in the area of cell; these are connected with the base station using optical fibre cables. When a subscriber is outside he is connected to the base station directly or connected via multiple hops from the antennas creating virtual massive MIMO network. Secondly an antenna array will be installed in every building; these antennas will be in line of sight with the base station. The communication inside is done using technologies like Wi-Fi, visible light communication, millimetre wave communication etc [1].

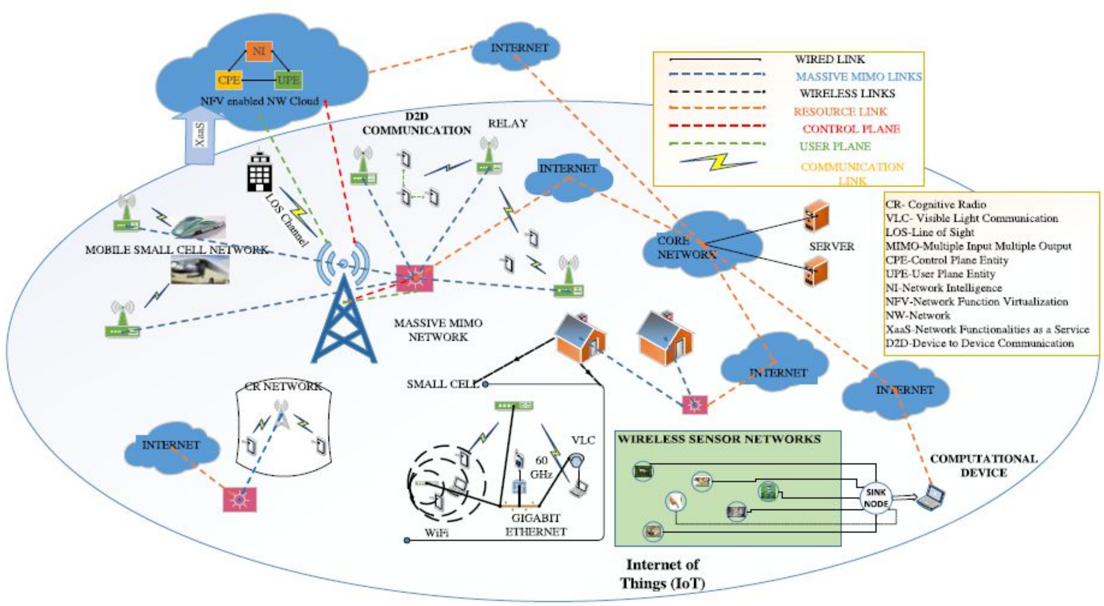

Figure 2: General 5G Cellular Network Architecture [7]

MILLIMETRE WAVE COMMUNICATION

The spectrum from 30 to 300 GHz is referred as millimetre wave band as the wavelength comes to be in millimetre range [2]. Millimetre waves are also known as extremely high frequency or very high frequency by the international telecommunications union (ITU) and they can be used for high speed wireless communication. Millimetre wave have high data rate. Microwave frequencies will provide a data rate of 1Gbps when it comes to millimetre frequencies they will provide data rate up to 10Gbps. They travel in a line-of-sight path. Due to very less diffraction property of the millimetre wave they are prone to blockage [1]. Hence they are used for communication in densely packed network like personal area network. With increasing demand for mobile communication, there is contradiction between the available bandwidth or spectrum and the capacity requirement. This is a key area of interest in 5G [1]. Millimetre wave band has been suggested for 5G mobile communication, which will provide services like high definition video and television [3, 4]. Currently research is going on in 28 GHz, 38 GHz, 60 GHz and E-band [1]. The devices being manufactured using CMOS technology are made to Work in millimetre wave band. There is great difference between the present microwave band and the millimetre band.

Extremely high frequency (ITU)	
Frequency range	30 to 300 GHz
Wavelength range	1 cm to 1 mm
Related bands	K / L / M bands (NATO) K_a / V / W / mm bands (IEEE)
Millimetre band (IEEE)	
Frequency range	110 to 300 GHz
Wavelength range	2.73 to 1 mm
Related bands	EHF (IEEE)

Figure 3: Millimetre Band Specification for ITU and IEEE

Suggests that millimetre wave have more coverage compared to the micro wave. There is going to be a challenge in the modification in physical layer, medium access layer and routing layer, so as to make millimetre wave to be used in 5G. There is a need for new insight in architecture and protocols to overcome some limitations like path loss, directivity, sensitivity to blockage and mobility in millimetre communication [5]. Due to high frequency there is a huge propagation loss, this might be overcome by using beam forming technique which also provide directivity. Compared to other lower bands, millimetre band have high atmospheric absorption; they are being absorbed by the gases in the atmosphere. This is why millimetre has less range up to 1 km. But researchers say that the impact of atmosphere and rain is negligible in small area (less than 1 km). When it comes to millimetre wave communication the cell size is around 200m, so there will not be much attenuation due to rain and atmosphere [6, 8]. It is considered that there might be an attenuation of 7 dB/km due to heavy rain, and 1.4 dB attenuation in the whole 200m distance [6].

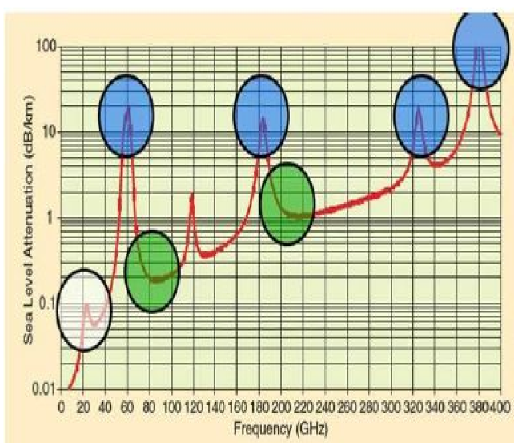

Figure 4: Atmospheric Absorption across MM-Wave Frequencies in dB/Km [7]

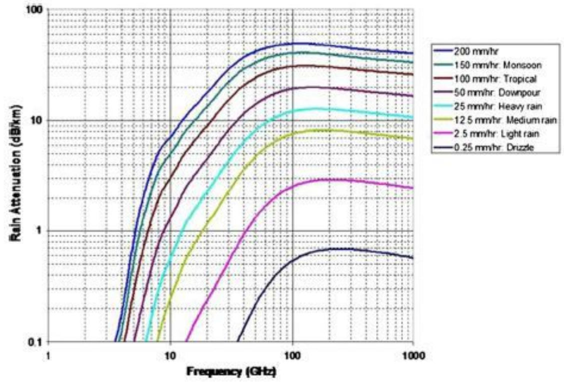

Figure 5: Rain Attenuation in dB/Km across Frequency at Various Rainfall Rates [6]

FEATURES OF 5G

To enhance such a wide range of technologies, 5G obviously have to concentrate on some parameters which lead to the requirements and capabilities for the network to differ from other generations. Some of them are listed below Energy consumption and low cost: It has been always the great challenge for mobile communication to provide the services and features for low energy and low cost. However, to avail all the services for wireless sensor network wherein we have millions of sensors, subsystems and actuators connected, work has been done in many energy efficient protocols and algorithms and thus in 5G they are yet to be implemented.

Performance of Network: As the device energy consumption was up to manageable with highenergy efficient algorithms there exists a problem of 'High Network Energy Performance' which is again a major emerging task for operator. Recent technologies are relaying on large solar panels for power supply, thus the energy problems in remote areas are widely handled by these solar panels.so energy efficient of large network is always a challenge for an operator to fulfil all its services [12].

Lower Latency: Latency is mainly defined as the delay response of the device. as the name suggest, it is the important parameter to achieve the promising services as higher data rates and high response time. However, to achieve the low latency it's always been a challenge for developers. As the 5G deals with higher data rates there exists a main issue of how to lower the latency. To support such lower latency applications should be given end-end latency of less than 1ms.

It is somehow achieved for fast growing applications as

- Traffic safety
- Control of infrastructure
- Industrial processes

High availability & Reliability: Another important aspect after lower latency is high availability and high reliability. High reliability includes the system services as well as hardware architecture where in high availability includes the channel bandwidth, providing a higher bandwidth is again a difficult task. Connectivity with the required characteristics is essentially available with less deviation [11].Very large System Capacity: Traffic services forcellular communication systems are dramatically increasing. To enhance with such traffic in simple way, 5th Generation networks must be capable of transferring data at much lower cost on bit rate compared to present networking system. However, in order to operate with the same or even lower the energy consumption, 5G has to work on lower energy consumption per bit delivered.

As compared with present scenario 5G system must be capable of supporting huge number of devices. Thus it's again a challenge for 5G operation in millions of wireless sensor networks which include sensors, actuators, sink, and sources etc. This challenge is mainly in terms of efficient use of protocols [13].

CHARECTERISTICS OF MMWAVE COMMUNICATION

Wireless channel measurement: Millimetre waves have many losses due to rain and atmosphere [6, 8] which limit the range of communication to at most 1 km or less. By using smaller cell size of 200m we can overcome this disadvantage [9]. Hence millimetre waves are used for indoor communication. There are many researches going on millimetre band at 60 GHz. The research says that the free space propagation losses are proportional to square of the carrier frequency. Free space propagation loss at 60 GHz is 28 dB more than that at 2.4 GHz, for a signal of wavelength 5 mm [10]. There is a peak oxygen absorption from 15 to 30 dB/km at 60 GHz [11]. [12] Shows that the non-line-of-sight (NLOS) communication channel suffers more attenuation than a line-of-sight (LOS) communication channel. The large scale fading F(d) is given as below:

$$F(d) = PL(d_0) + 10nlog_{10}\frac{d}{d_0} - S_0 \quad (1)$$

Where, PL(d0) = the path loss at reference distance d0

n = the path loss exponent

Sσ= the showing loss

σ= standard deviation of Sσ

The statistical parameters in the path loss model given table below

Table 2 shows the statistical parameters in path loss model taken in a corridor, a LOS hall and a NLOS hall [12].

Table 2: Statistical Parameters in the Path Loss Model

$PL(d_0)$[dB]	n		σ[dB]
Corridor	68	1.64	2.55
LOS hall	682.17	0.88	
NLOS hall	68	3.01	1.55

It is clear that the path loss in NLOS is more than the LOS from the readings of n, i.e. the path loss exponent. This can be overcome by using directional antennas at the transmitter and receiver; hence we achieve high antenna gain. Where as in small scale fading at 60 GHz directional antennas cannot be used for reducing path loss, here we need to use antennas with circular polarization and receiver antenna with narrow beam width [13, 14]. LOS communication must be used in millimetre wave for achieving high data rate and good power efficiency [15].

Directivity in MMWave: MMWave are highly directional, a single antenna cannot produce a beam of required power for transmission; hence arrays of antennas are used. The antennas produce signals in phase, so that signal from each antenna adds up producing a signal which can be transmitted. This produced beam has high gain in a particular direction and very low gain in other directions. A beam training procedure is used for directing beam from the transmitter to receiver. There are many beam training algorithms are available for reducing the beam training time.

Sensitivity of Blockage: Since mmWave have low wavelength compared to the obstacles, they are getting blocked. Scattering is happening only when the wavelength of the signal is more than the size of the obstacles. Hence due to less scattering properties of mmWave they are getting blocked. Even by human there is blockage of signal. MmWave are highly sensitive to blockage.

CHALLENGES IN MM WAVE COMMUNICATION

Integrated Circuit and system design: As in mmWave we are going to have high carrier frequency and wide bandwidth, there is going to be a great challenge in designing circuits and antennas that could work for micro wave range [7]. At 60 GHz band we will use signal with high transmit power and huge bandwidth, this may cause the power amplifiers to be nonlinear [16]. Phase noise and IQ imbalance are the major challenges faced by the integrated circuits working at radio frequency [16].

Interference Management and Spatial Reuse: Due to the use of directional antennas there is very less interference. The mesh network at 60 GHz outdoor model uses highly directional links known as pseudowired, so the interference between the nonadjacent links is negligible [18]. Antenna parameter details for antenna design may also be ignored in MAC protocol design. Due to direction antenna the third party cannot sense the carrier as in Wi-Fi; this is known as deafness problem [17]. So a coordination mechanism becomes a key for the design of MAC protocol, all the transmissions should be exploited to enhance the network capability [10].

User Mobility: Mobility of user possesses a great challenge to the mmWave communication. User mobility will cause a significant change in the channel state. When a mobile user moves, the distance between the user and base station varies and hence the channel state information changes. So the selection of modulation and coding scheme should be performed according to the channel state information [19]. Due to small coverage area i.e. in indoor environment, user mobility will cause load fluctuation.

APPLICATIONS OF MMWAVE

They are commonly used in radio astronomy that does research on celestial objects and remote sensing. In US 38.6 to 40 GHz band is used as licensed high-speed microwave communication in future may be the 60 GHz band may be used as unlicensed high speed mmWave communication for short range. MmWave radar are used in battle tanks, aircraft and ships to shoot down missiles of the enemies using fire control radar. MmWave are used for security screening, recently imagers are being used in airports for scanning as the cloths and other organic materials are translucent to mmWave. Police use speed radar for determining the speed of vehicles for law enforcement and road safety. They are also used in medicine for the treatment of many diseases.

CONCLUSIONS

5G will provide great speed and enough capacity; it's like wherever the mobile station moves there will be no drop in speed even though any numbers of mobile users are connected to the network at the same time.MmWave band is going to be used in future; it's a wide band and have many challenges to overcome to reach the required standards. TDMA, FDMA and other multiple access techniques may not be applicable to provide good capacity efficiency as the frequency and time are limited. So we need a new technique which is compatible with the mmWave band and can improve the capacity. If all things fall in place 5G may be applicable by 2022/23. So there is going to be a Bright future ahead.

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AUTHOR'S DETAILS

Adusumalli Mallikharjuna Rao received B.Tech degree from Jawaharlal Nehru Technological University Hyderabad, Telangana, India in 2014. He is currently working toward his M.Tech degree at the Department of Electronic and Communication Engineering, Lovely Professional University, Punjab, India. His research interests include propagation models in millimetr wave band used in 5G, Device to Device Communication and Millimetre wave communication.

Sk Saddam Hussain received B.Tech degree from Jawaharlal Nehru Technological University Hyderabad, Telangana, India in 2014. He is currently working toward his M.Tech degree at the Department of Electronic and

Communication Engineering, Lovely professional University, Punjab, India. His research interests include massive MIMO system, Beam Division Multiple Access, Device to Device Communication and Millimetre wave communication.

Koushik Barman has received his M.Tech from NIT Hamirpur (H.P) in 2011. He is presently working as Assistant Professor at School of Electronics and Electrical Engineering, Lovely professional University, Jalandhar, Punjab. He is also pursuing Ph.D from Lovely professional University. His area of interest is Wireless Communication Networks.